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Phosphorus Fertilizer Application in Crop Production

Introduction

Phosphorus, like nitrogen and potassium, is required in relatively large amounts by plants. It is second only to nitrogen in fertilizer use in Alberta.

Phosphorus occurs in most plants in concentrations between 0.1 and 0.4%. The most essential function that phosphorus has in plant life is in energy storage and transfer. Energy obtained from photosynthesis and metabolism of carbohydrates is stored in phosphate compounds in plants for use in growth and reproduction. A deficiency of phosphorus will retard overall plant growth.

Phosphorus in the soil

Soils of Alberta are often high in total phosphorus, frequently containing over 1350 kg/ha (1200 lb/ac) in the top six inches. However, the portion of utilizable phosphorus in native soils is frequently low. Much of the unavailable phosphorus is contained in soil minerals and in soil organic matter. The term "available phosphorus" is used to indicate the soil phosphorus utilizable for crop growth. It also refers to the portion of soil phosphorus removed by various extractants in soil testing laboratories.

Phosphorus availability to plants can be assessed by measuring the phosphate concentration in the soil solution and the ability of the soil to maintain the soil solution concentration. The quantity of phosphorus in the soil solution, even when at relatively high levels, is only in the range of 0.3 to 3.0 kg/ha (0.3 to 3.0 lb/ac). Rapidly growing crops will absorb about 1 kg/ha (1.0 lb/ac) of phosphorus per day. Therefore, soil solution phosphorus must be replenished by the "labile" pool of phosphorus. Labile phosphorus is a pool of phosphorus which has the capability to undergo rapid chemical or biological change to recharge the available phosphorus pool.

Three different soil tests are used by soil testing laboratories in Alberta. The Miller-Axley method (a double acid extractant) is used by the government laboratory. The modified Bray (also a double acid extractant) and the Olsen Method (an alkaline extractant) are also in use. No one method performs best in all soils.

All methods were developed and tested before phosphate fertilizer use became widespread. The methods work reasonably well on soils that have not received much phosphate fertilizer. However, the phosphorus level in some soils has been built up by phosphorus fertilization over the years and as a result they are no longer responsive to fertilizer phosphorus application. None of the soil tests perform very well in predicting the true amount of labile phosphorus which has accumulated from applications of phosphate fertilizer.

Phosphorus uptake by plants is not only affected by the amount of available phosphorus in soil but by other factors as well. Environmental conditions such as low soil moisture or low soil temperature will reduce plant uptake of phosphorus. Other factors such as rate of phosphorus fertilizer applied, method of application and chemical form will all affect phosphorus uptake.

Crop response to applied phosphorus fertilizer depends, to a large extent, on the quantity of plant available phosphorus already in the soil. Table 1 gives the general soil test ratings for phosphorus.

Phosphorus is not very mobile in the soil and therefore the concentration of phosphorus is greatest in the surface soil. Therefore, the soil test ratings are based on a 0-6 inch sample depth.

Economic yield responses to phosphorus fertilizer can be expected when soil test values are less than 10 lb/ac of P and pH is less than 7.2. Even soils that test medium to high may show yield responses 25 to 30% of the time.

TABLE 1: Soil Test Rating for Phosphorus*

Soil Test Level Rating	Phosphorus (lb/ac)
very low	0 to 10
low	11 to 25
medium	26 to 50
high	> 50

*Source: Alberta Agriculture Soil and Animal Nutrition Laboratory, using the Miller-Axley (NH_4F-H_2SO_4) extractable phosphorus method.

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In situations where large yield increases are obtained, the actual uptake of the fertilizer phosphorus by the plant will vary from 20 to 30% in the year of application. The unused phosphorus (referred to as *labile* or *residual* phosphorus) remains in the surface horizon of the soil. The availability of this residual phosphorus to subsequent crops is highly variable among soil types.

For phosphorus to be absorbed by plant roots it must move in the soil solution (soil water) by diffusion, which is a slow process. Most small grain crops take up about 70% of their required phosphorus in the first 40 days after emergence. Therefore, placement of phosphorus fertilizer near the seedling root is more important than with most other plant nutrients.

Types of phosphorus fertilizers

Tables 2 and 3 list the common phosphorus fertilizers and mixtures of fertilizers containing phosphorus respectively.

Monoammonium phosphate, which is the most common form of phosphate available in Alberta, can be blended with either ammonium nitrate or urea to produce various blends. It can also be blended with muriate of potash (0-0-60, 0-0-62) or with most sulfur fertilizers as well.

Most soil testing laboratories in Alberta report soil test levels of phosphorus as P in lb/ac but fertilizer recommendations are made in terms of P_2O_5 in lb/ac. To convert P to P_2O_5, multiply by 2.3 (e.g., 10 lb/ac of P = 23 lb/ac of P_2O_5). Phosphorus fertilizer in Alberta is sold on the basis of P_2O_5 in percent of total product.

Table 2: Phosphate fertilizers

NAME	GRADE	CHEMICAL FORMULA	PHYSICAL PROPERTIES	OTHER CONSIDERATIONS
Monoammonium phosphate	11-51-0 11-55-0	$NH_4H_2PO_4$	Solid, granular, does not absorb moisture during storage, fairly resistant to breakdown during handling.	Most commonly used high analysis solid phosphorus source in Alberta. Higher availability to plants than other source.
Diammonium phosphate	18-46-0	$(NH_4)_2HPO_4$	Same as monoammonium phospate.	P availability to plants is slightly less than monoammonium phosphate. Not widely available in Alberta. Is more common in the USA.
Monocalcium phosphate (Triple Super)	0-45-0	$Ca(H_2PO_4)_2$	Same as monoammonium phosphate.	P availability to plants is slightly less than monoammonium phosphate. Not widely available in Alberta.
Ammonium polyphosphate solution	10-34-0	$(NH_4)_xH_{n+2-x}(P_nO_{3n+1})$	Liquid, must be stored above -18°C to maintain liquid state. Is corrosive to some metals.	A phosphate fertilizer available in many parts of Alberta. P availability similar to that of monoammonium phosphate.

Table 3: Mixtures of Fertilizers Containing Phosphate

NAME	GRADE	CHEMICAL FORMULA	PHYSICAL PROPERTIES	OTHER CONSIDERATIONS
Ammonium phosphate sulphate	16-20-0(14)	$(NH_4)_2SO_4$ + $NH_4H_2PO_4$	Solid, granular, a mixture of 21-0-0 (24) and 11-51-0	Suitable for sulphur deficient soils, P availability same as monoammonium phosphate.
Ammonium nitrate phosphate	23-23-0 17-34-0 etc.	NH_4NO_3 + $NH_4H_2PO_4$	Solid granular blend of 34-0-0 and 11-51-0. Will absorb moisture in storage or during handling.	Suitable for N & P deficient soils. P availability same as monoammonium phosphate. Maximum safe rates of nitrogen for seed placement higher than for urea ammonium phosphate.
Urea ammunium phosphate	28-28-0 17-34-0 etc.	$CO(NH_2)_2$ + $NH_4H_2PO_4$	Solid, granular, a mixutre of 46-0-0 and 11-55-0 fairly stable during handling, particularly if urea component is coated.	Suitable for N & P deficient soils. P availability same as monoammonium phosphate. The urea component can cause germination damage if seed placement is above recommended rates.
Urea phosphate (acid fertilizer)	Numerous blends	$CO(NH_2)_2$ + H_3PO_4 + H_2SO_4	Blend of urea, phosphoric acid, and sulfuric acid. Blends have very low pH often about 1.0. Is corrosive and requires specialized handling and application equipment.	First marketed in Alberta in 1985. P availability is slighty less in bands compared to monoammonium phosphate.
Mono ammonium phosphate suspension	10-30-0	$NH_4H_2PO_4$	Produced by grinding 11-51-0 or 11-55-0 and mixing with water to form a liquid suspension.	Requires agitation during application. Discuss with local supplier.

Methods of phosphorus application

There are a number of methods of applying phosphorus fertilizer. Figure 1 shows examples of fertilizer placement. Some methods are more efficient than others. To obtain good phosphorus fertilizer efficiency adequate rates of nitrogen and other nutrients, if required, are necessary to achieve optimum crop production.

Broadcast and Incorporation

This method involves uniformly broadcasting and incorporating phosphorus fertilizer into the soil before seeding. At low and medium soil test levels for phosphorus, the broadcast and incorporation method is usually less effective than seed placed or banded phosphorus. When phosphorus is broadcast and incorporated, application rates may have to be two to four times the in-row banded rate to obtain an equal crop response. Therefore, broadcast/incorporation of phosphorus may not be economical if high rates are required to obtain a yield increase. On soil types known to give a good residual response to phosphorus, broadcast applications may be economical in the long term.

High rates of broadcast/incorporated phosphorus on eroded soil areas or knolls are recommended to even out the fertility of eroded fields. Knolls are frequently low in soil phosphorus.

Broadcasting phosphorus at high rates involves a high initial cost. The availability to plants of applied phosphorus decreases over a period of years because of the reaction products formed in the soil.

When high rates of phosphorus fertilizer are applied, it is possible to induce micronutrient deficiencies.

In southern Alberta, where high rates of phosphorus have been applied, isolated cases of zinc deficiency have been observed during cool wet spring conditions in both irrigated field beans and in corn grown on sandy soils. The extent to which yield-limiting micronutrient deficiencies can be induced is not yet known in Alberta.

Top dress (broadcast - no incorporation)

Broadcasting phosphorus fertilizer without incorporation is only recommended for established forage crops because it is the only practical method currently available. Phosphorus fertilizer is immobile, therefore plant uptake of fertilizer phosphorus can be low in the first year after application. Alfalfa and grasses do have feeder roots very near the soil surface and can take up some broadcast phosphorus fertilizer. For forage crops, a two to three year supply of phosphorus can be either deep banded or broadcast and incorporated before establishment. Subsequent applications may be top dressed.

Seed placed phosphorus (banded in-row with seed)

With this method, phosphorus is placed directly into the seed row with the seed. This is a very effective means of phosphorus application, provided that the amount applied is not toxic to the seed or seedling. Phosphorus fertilizer recommendations in Alberta are currently designed for banding with or near the seed. Recommended rates are not applicable to broadcast incorporated phosphorus because of reduced efficiency.

When soil conditions are dry, the phosphorus fertilizer placed in-row may become stranded in dry surface soil, reducing its uptake.

The maximum safe rate of phosphorus that can be applied with the seed for cereal crops is 40 to 55 kg/ha (35 to 50 lb/ac) of P_2O_5. For oilseed and pulse crops seed-placed P_2O_5 rates should not exceed 28 kg/ha (25 lb/ac) especially when a seeding implement which places the seed and fertilizer in a narrow band (double disc drill) is used. Standard single and double disc drills cut a fairly narrow furrow and place the seed and fertilizer together in the bottom of the furrow. These drills place the fertilizer in a concentrated band close to the seed and are most likely to result in damage to sensitive crops at high rates of application.

Disker and hoe type drills cut a wider furrow and the seed and fertilizer are scattered across the bottom of the furrow. This scattering in a wide band results in a lower concentration of fertilizer close to the seed and is therefore less likely to cause damage to sensitive crops when high rates of fertilizer are applied.

Seeding implements which scatter the seed in wide bands (diskers, air seeders, hoe drills) reduce the seed-fertilizer contact. As a result, somewhat higher seed-placed phosphorus rates can safely be used. However, because of the wide variation in furrow opener design and spacing, and width of seed row, specific maximum safe seed-placed phosphorus rates have not been determined for these implements. Generally, rates can be increased by 25 to 50 per cent. At low rates of fertilizer application, response to seed-placed P may be slightly less when the seed and fertilizer are spread out in broad bands as compared to narrow bands.

Side banding phosphorus

This method places the phosphorus in a band near the seed row during the seeding operation. The fertilizer is normally banded 2.5 to 5 cm (1 to 2 inches) below and to the side of the seed row for small seeded crops and row crops such as sugar beets, potatoes, sunflowers, corn and beans. Phosphate at all recommended rates can be applied with this method. However, specialized seeding equipment is required. Yield increases obtained with this placement are usually at least equal to seed-placement at low rates of application, but much superior when application rates are too high for safe placement with the seed. For cereals, phosphorus banded near the seed is similar in efficiency to seed-placed phosphorus.

Some new minimum till and no-till seed drills are using a new mid-row or paired-row technique. Two rows are seeded about 7.5 cm (3 inches) apart and phosphorus is sidebanded between the two rows about 5 cm (2 inches) below the seeding depth. There is an 18 to 25 cm (7 to 10 inch) space between the next pair of rows.

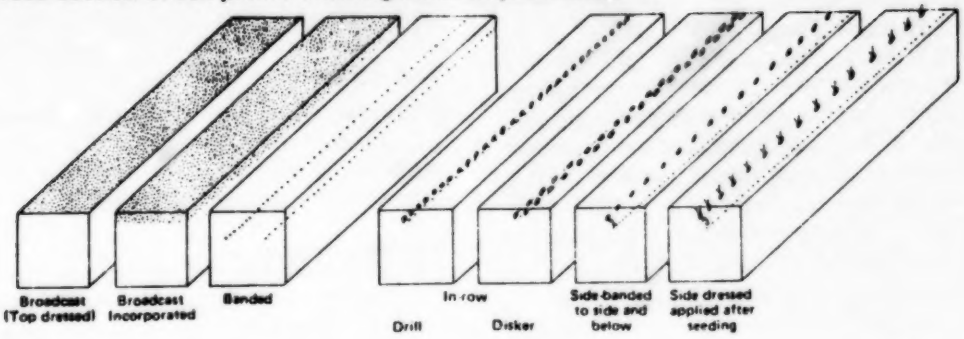
Banding phosphorus

This method of application places phosphorus in concentrated bands in the fall or spring before seeding. A cultivator type implement with shovels or knives is used with a shank spacing of 20 to 35 cm (8 to 14 inches). Depth of application is normally 8-15 cm (3 to 6 inches).

Deep banded phosphorus is often as effective as seed-placed phosphorus when phosphorus rates which can be safely seed-placed are compared. Both are much more effective than broadcast phosphorus when soil test levels are low. In some locations and years, particularly on very low P soils and when soil temperature is low following seeding, the "starter" effect of phosphate placed with or near the seed can be important and cannot be achieved by deep banded phosphate alone. For this reason, seed placement of a portion of the phosphorus at 11 to 17 kg/ha (10 to 15 lb/ac) P_2O_5 is advised when phosphate is deep banded.

Deep banded phosphorus may be more effective than seed-placed phosphorus in some years, generally under dry surface soil conditions. The major advantages of banding phosphorus are: a) rates which are too high for seed-placement with oilseeds and pulse crops can be used where low soil phosphorus warrants such rates, and b) the amount of fertilizer handled at seeding time can be reduced or, in some situations, eliminated. Application of phosphate both with the seed and deep banded (split application) is an effective way to achieve the benefits of both methods.

Figure 1. Cross-section of soil profile showing fertilizer placement.



Narrow spacing between phosphate bands is preferable, so that phosphate uptake is not delayed during early growth owing to long distances between the bands and some of the seedlings. On very low phosphorus soils, "stripping" can occur caused by poorer growth of plants midway between phosphate bands if the bands are too widely spaced. For phosphate, deep banded spacings in excess of 30 cm (12 inches) are not recommended, and narrower spacings may be more effective particularly where no phosphate is seed-placed.

When banding phosphate depth of placement has little if any consistent effect on fertilizer efficiency. However, the bands must be sufficiently deep to avoid disruption by subsequent tillage and seeding operations. Time of phosphate banding (fall *vs* spring) appears to have little effect on fertilizer efficiency.

Another type of banding that is in the experimental stage is injecting liquid fertilizer into the soil at high pressure. Pressures of 2000 to 6000 psi (pounds per square inch) are being tried. If this method can be developed, it will be ideal for banding fertilizer in no-till cropping systems and on hay and pasture fields. Even dribble banding fertilizer in bands onto the soil surface and then plowing to turn the soil over has been shown to work as an alternative to deep banding in some situations.

Phosphorus fertilizer recommendations

The optimum phosphorus placement method varies with the crop to be grown and the level of available phosphorus in the soil. Annual crops may be placed in five groups depending on the response to phosphorus placement. The placement recommendation for each group of crops is discussed in relation to soils low in available phosphorus where crop response is consistently high, and in soils medium to high in available phosphorus where crop response is lower and more variable.

Note that the phosphorus recommendations in Western Canada are currently designed for banding with or near the seed for most crops. These lower rates are not applicable when phosphorus is surface applied and incorporated.

Table 4 provides general phosphate fertilizer recommendations for a number of crops grown in Alberta.

Table 4: General phosphorus fertilizer recommendations for crops grown in Alberta at increasing levels of P in the soil based on the Miller-Axley method of extracting soil P.*

Soil Test Level	Grains	Mustard, Canola & Flax	Peas, Beans	Potatoes Sugar Beets Corn	Alfalfa
P lb/ac (0-6")			P_2O_5 lb/ac		
0	50	30	70	90	60
10	40	25	60	80	50
20	30	20	50	70	40
30	20	15	40	60	30
40	15	10	30	50	20
50	10	10	20	40	10
60	10	10	20	30	10
70	10	10	20	20	0
>80	10	10	20	20	0

*Source: Alberta Agricultural Soil & Animal Nutrition Laboratory.

NOTE: Recommendations listed are general; specific recommendations will vary depending on: location in the province, soil zone, soil texture, soil pH, past field cropping history and free zinc in soil.

Cereal crops:

Soils low in available phosphorus

On most of these soils placement of fertilizer phosphorus in the row with the seed at all recommended rates is equal to or better than banding near the seed and better than surface application and incorporation.

If phosphorus is surface applied and incorporated, the annual application rate must be 2 to 4 times the rate recommended for seed placement in order to obtain equal crop response in the year of application.

Soils medium to high in available phosphorus

Placing fertilizer phosphorus with or near the seed on these soils at rates up to 28 kg/ha (25 lb/ac) P_2O_5 may result in a crop response 25 to 30 per cent of the time.

Rapeseed, mustard, annual legumes and buckwheat:

Soils low in available phosphorus

On these soils, phosphorus rates up to 28 kg/ha (25 lb/ac) P_2O_5 can be banded with the seed.

Rates greater than 28 kg/ha (25 lb/ac) P_2O_5 should be banded approximately 2.5 cm (1 inch) beside and below the seed, or deep banded.

Soils medium to high in available phosphorus

Placing fertilizer phosphorus with or near the seed on these soils at rates up to 28 kg/ha (25 lb/ac) P_2O_5 may result in crop response 25 to 30 per cent of the time.

Flax:

This crop does not readily respond to fertilizer phosphorus banded WITH the seed.

Soils low in available phosphorus

On these soils all phosphorus should be banded approximately 2.5 cm (1 inch) directly below the seed.

Soils medium to high in available phosphorus

Banding of phosphorus near the seed on these soils at rates of 28 kg/ha (25 lb/ac) P_2O_5 may result in a crop response.

Corn, potatoes and sunflowers:

Soils low in available phosphorus

On these soils, all phosphorus should be banded near the seed row.

Soils medium to high in available phosphorus

Banding of phosphorus near the seed on these soils may result in a crop response 25 to 30 per cent of the time.

Sugar beets:

Soils low in available phosphorus

On these soils, phosphorus up to 22 kg/ha (20 lb/ac) P_2O_5 should be banded with the seed. Rates greater than 22 kg/ha (20 lb/ac) P_2O_5 should be banded approximately 2.5 cm (1 inch) below and 2.5 cm (1 inch) beside the seed.

Soils medium to high in available phosphorus

Banding of phosphorus with or near the seed in these soils may increase seedling vigor which may or may not carry through to increase yield.

Forage crops:

The optimum method and time of application of fertilizer phosphorus for cultivated grasses, grass-legumes and legumes is broadcast-incorporation or deep banding before seeding. Phosphorus applied in this manner will suffice for the year of establishment and up to eight years afterward, depending upon rate of application, available phosphorus levels and other soil characteristics. On soils low in available phosphorus a single high rate (150 kg/ha or 125 lb/ac) of P_2O_5 broadcast and incorporated prior to seeding has shown better yield response over a 3-year period than an equivalent amount broadcast in annual increments. However, phosphorus requirements for established forage stands can be supplied by broadcast applications particularly under irrigated conditions. In the future it may be possible to band fertilizers into established forage fields by injecting liquid fertilizer using extremely high pressure.

Summary

The ideal situation for crop production is to have a good supply of phosphorus close to the seed during the first month of growth and an adequate quantity of phosphorus in the soil for the rest of the season. Most of our soils do not approach this ideal. Placement of phosphorus in-row with the seed has been the traditional method used for phosphorus fertilization in Alberta. More recently, preplant banding of phosphorus with nitrogen has been found to be a good alternative method of application. Under conditions of low soil phosphorus and low soil temperatures, some "starter" phosphorus in the seed row will be beneficial.

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